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Development of Lean Manufacturing Course Material

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Submitted to:
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Abstract

Our goal was to develop lean manufacturing course material for high school students in machine tool technology programs. In addition to developing a potential curriculum, we researched different lean manufacturing principles and decided that a module on 5S Visual Management would be best suited for the first teaching module. We were able to test the module and gather the necessary feedback required to improve it.

Table of Contents

Abstract 2
Table of Contents 3
List of Figures 4
Introduction 5
Objective 5
State of the Art 5
Rationale 6
Introduction to Lean Manufacturing 6
Approach 15
Methods 15
Project Organization 15
Survey Creation and Implementation 15
Lean Manufacturing Research 17
5S Teaching Module Creation 17
5S Teaching Module Testing 19
Results 19
Survey 19
Chicopee Comprehensive High School Feedback 19
Local Manufacturing Firm Feedback 20
College-Level Manufacturing Class Feedback 20
Discussion 20
Logistical Issues with Survey 20
5S Teaching Module Development 21
5S Module Proctor Copy Development 21
5S Teaching Module Testing and Feedback 21
5S Teaching Module Revision 22
Project Continuation 22
Conclusions 23
Appendix 24
IRB Information 24
Survey Drafts 28
5S Teaching Module and Proctor Copy 30
Sample Presentation from Local Manufacturing Firm 56
Works Cited 62

List of Figures

Figure 1- Lean Manufacturing Principles 7

Figure 2- Basic Value Stream Mapping Flow Chart 7

Figure 3- Continuous Flow Production 9

Figure 4-Cellular Layout 9

Figure 5- Flow Chart of 5S 13

Figure 6- Implementation process of 5S 14

Figure 7-IRB Approval Form 24

Figure 8-IRB Application Form, page 1 25

Figure 9-IRB Application Form, page 2 26

Figure 10-IRB Application Form, page 3 27

Figure 11-Survey Rough Draft 28

Figure 12-Final Survey 29

Introduction

Objective

Create training material available on the internet in order to enhance the educational experience for high school students in a machine tool technology program at no cost to the individual schools.

State of the Art

A simple Google search will yield numerous results for online lean manufacturing courses. Most of these sites have a variety of modules including 5S Visual Management. Each website gives a brief description of the content in the modules and other material that is available with a subscription. Most of the websites require the purchase of a subscription to the site which ranges from 3 months to 1 year and they vary in price.

For example, the development of lean course material has been visited by a company called Lean Marketplace.[1] This company offers a program which includes various modules on lean principles such as 5S, Lean Management, Lean Maintenance, and others. This program also offers presentations and resource assistance for developing course curriculums and student projects. A subscription to the Lean Marketplace costs $69.99 every three months.

Productivity Innovation[2] is also another website that offers various teaching modules. This site offers 5S visual management for $279.00 for a one month subscription. The 5S Visual Management program consists of seven separate modules: Introduction, Sort, Set, Shine, Standardize, Sustain, and an implementation module. This site also offers a variety of exercises, handouts, worksheets and templates.

[1] http://www.leanmarketplace.com/

[2] http://www.productivityinc.com/products/programs.shtml

The purpose of this IQP is to develop material that can be used to help teach high school machine tool technology students. The material will be interactive with various forms of multimedia, questions and answers, and activities for students to do. The material developed in this IQP differs from other companies' products because it is free to use and access, thereby alleviating the high cost of similar material for schools that may already have a tight budget.

Rationale

In the competitive job market, many technical high school graduates find it difficult to find employment. As such, it is imperative that they have the necessary skills that are on par with or exceed the industry standards. Companies are now starting to heavily rely on lean manufacturing principles, and unfortunately some current curriculums at the technical high school level do not incorporate or have overlooked these principles. By sending out a survey to manufacturing teachers at vocational high schools, we hoped to learn what principles the teachers want to teach and what principles might be missing from the current curriculums. However, we were unable to collect data from this survey due to logistical complications. Therefore we decided to create presentation material on 5S because it is a fundamental technique for lean manufacturing.

Introduction to Lean Manufacturing

The objective of a lean approach to manufacturing is to maximize the value of the product to the customer while minimizing waste. Many companies in the manufacturing industry use lean manufacturing principles (LMP) to maximize their profit, minimize their cost of production, and eliminate waste. Lean principles can be applied to nearly anything from optimizing management to developing vertical and horizontal integration that help with optimizing the flow of products. Figure 1 shows several tools which can be used to promote lean manufacturing.

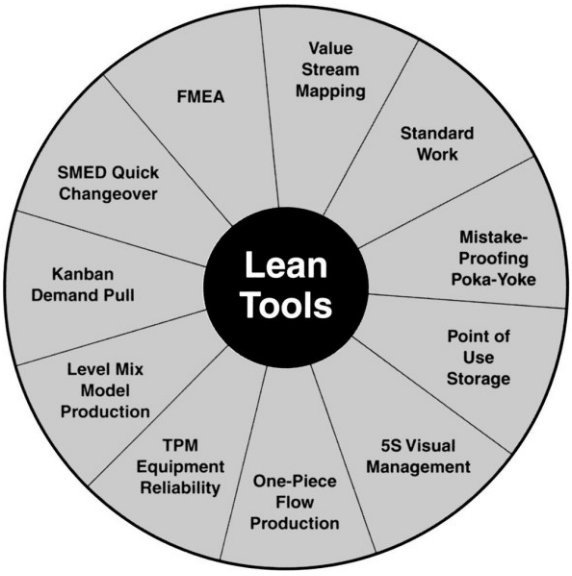

Figure 1- Lean Manufacturing Principles[3]

Value Stream Mapping: A flow chart that incorporates symbols and pictures to depict the flow of material and other information. Value Stream Mapping is used to provide the customer with maximum satisfaction along with creating a process with minimal waste in design, assembly, and sustainability. (George, 2002, pp. 51-55)

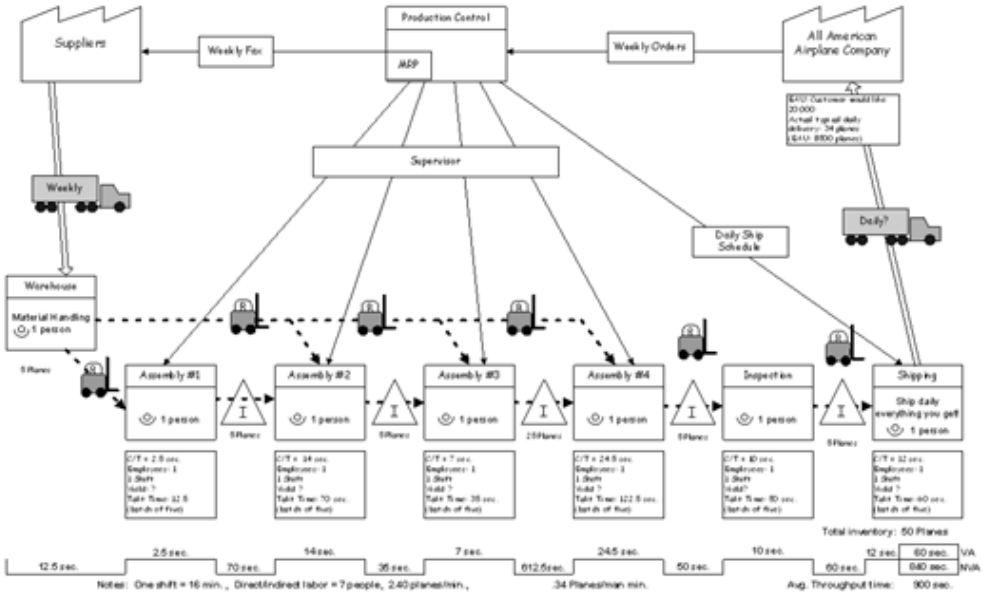

Figure 2- Basic Value Stream Mapping Flow Chart[4]

[3] http://www.bexcellence.org/Lean-manufacturing.html

Standard Work: By creating a process that is standardized, a baseline process is created enabling for continuous improvement to occur for that particular process. Standardizing work usually consists of three basic principles: Takt time, a precise work sequence which tasks are performed inside of the takt time window, and a standard inventory which could include machines or products. Standard work is the basis for many of the lean principles used today.

Poka-Yoke: This Japanese term refers to mistake proofing devices. These devices are often built into or interlocked with machinery or fixtures to prevent missing an operation or loading the part wrong. (Fisher, 1999)

Point of Use Storage: This is a process where materials are stored in a particular work area where they are used and easily accessible. This allows for the simplification of physical inventory tracking, storage, and handling. The point of use storage method is best utilized when suppliers deliver small shipments frequently and timely.

5S Visual Management: Visual management allows for the production floor to be analyzed quickly and easily. 5S incorporates five stages to reduce distractions, clutter, and potentially hazardous situations: Sort which gets rid of trash and clutter, Set which is to ensure that every tool has its own place, Shine which ensures that the workplace is clean and well maintained, Standardize which makes the production process consistent, and finally Sustain which allows for the process that was refined by the four previous stages to remain in working condition. (Monden, 1993, pp. 199-219)

One-Piece Flow Production: One-piece flow production, also known as continuous flow production, is a manufacturing technique where parts move from one operation smoothly to the next without a wait or Work-in-Progress (WIP) in between steps. In the past, many companies would manufacture a batch of parts with the entire batch moving one step at a time. This method tends to create a bottleneck where excess parts build up at a slower step. Using batches can also cost a company significantly more money when a defect is found because an entire batch of product can be ruined. Continuous flow allows parts to arrive at the next step just as they are needed. This method results in a more efficient use of machine time and floor space. (Hobbs, 2004, pp. 17)

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[4] http://www.sdleansolutions.com/images/vsm2.gif

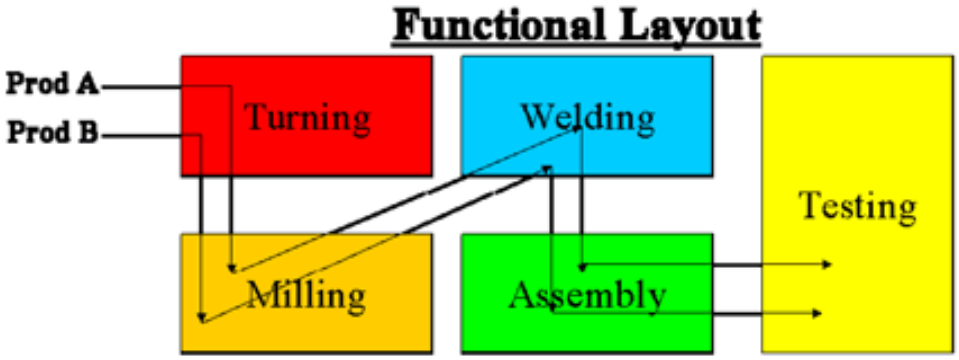


Figure 3- Continuous Flow Production[5]

Continuous flow production works best in a cellular layout where the different machines for each step are close to each other. This design allows parts to move quickly from step to step.

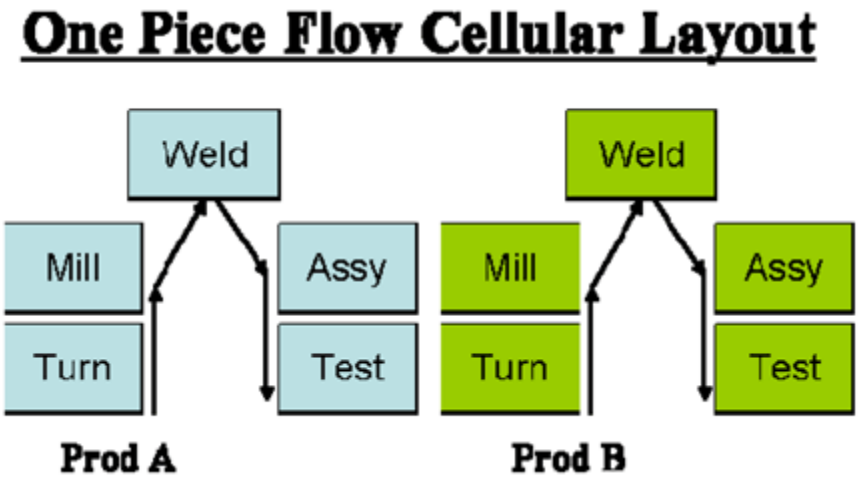


Figure 4-Cellular Layout[6]

One-Piece flow does not always work. Some cases when this method will be inefficient are:

- If a particular process has a high probability of creating a defective part, the next step will not receive a part and machine time will be wasted.
- If process times are not consistent, you cannot design a continuous flow system because you never know when a part will be ready to move to the next step
- If machine equipment has low reliability.
- If processes cannot be scaled to take approximately the same amount of time as the slowest step.

[5] http://www.reliableplant.com/Read/14703/one-piece-flow

[6] http://www.reliableplant.com/Read/14703/one-piece-flow

TPM Equipment Reliability: Total Productive Maintenance Equipment reliability deals with ensuring that machines are running as much as possible. While half of all downtime is due to employee breaks and regular maintenance, the other half is due to unscheduled downtime like malfunctions, breakdowns, material shortages, or employee error. This half of downtime is what TPM eliminates. (George, 2002, pp. 214-217)

Level Mix Model Production: Level mix model production analyzes areas of production with excess parts and areas with a shortage of parts with the intent of providing supply equal to demand. This system eliminates space wasted with a stockpile and time wasted waiting for products to arrive. It also helps a company better match customer demand quickly by allowing for smaller batch sizes that allow production to flow more smoothly. (Monden, 1993, 24)

Kanban: Kanban is a system that utilizes signs and signals to determine when to replenish supplies. It simplifies how inventory is tracked and managed by alerting staff when they need to order materials. This allows companies to better match production with demand. The goal of Kanban is to maintain a rapid manufacturing pace while lowering the cost of maintaining inventory. (Monden, 1993, pp. 15-35)

SMED Quick Changeover: Single Minute Exchange of Dies, or Quick Changeover, is a system created to keep a product moving through various production steps by keeping the time between steps to a single-digit minute (0-9min).

FMEA: Failure Mode Effects Analysis is a process that identifies potential places of failure in a manufacturing process. The possible failures are then ranked by the severity of their consequences, the potential failure frequency, and the failure's ease of detection. FMEA also keeps track of past failures in an effort to continually improve production. In order to be effective, FMEA must be involved in all steps of designing a production process. (George, 2002, pp. 190-191)

Eliminating waste is a major part of creating and developing a lean process. A major part of developing a lean process is eliminating waste, the most obvious of which is material waste created by inefficient machining processes. Other types of waste addressed by lean processes are stockpiling of incomplete parts in an inefficient process and wages of workers who do jobs

that could be automated. The most important waste addressed is perhaps waste created by errors in machining. This particular waste is multi-faceted because it not only involves re-making faulty parts, but also the fact that companies have to inspect parts in the first place to see if they are good. Processes that are lean will eliminate as much waste as possible all along the path from raw material to finished part. If waste is eliminated along the entire value stream rather than focusing on isolated points, it creates processes that do not need constant attention from employees which in turn maximizes space efficiency and productivity.

While the manufacturing industry tends to be most associated with lean principles, other industries can benefit as well. For instance, businesses and government can streamline their processes and increase efficiency by applying lean principles. These companies may or may not refer to their new principles as "lean," but they still have the same end goal of reducing cost and increasing efficiency. This paradigm shift towards lean principles shows that a company is eliminating outdated and inefficient processes in favor of newer, more efficient methods.

Origin

Many people believe that the principals involved in lean manufacturing originated with the Toyota Motor Corporation. However, Henry Ford really started implementing lean principles like standardization of parts, waste reduction, and limiting downtime between production steps in the early 1900s. Ford's assembly line revolutionized the production of automobiles from a series of complicated steps that required a high level of knowledge to a longer series of simpler steps that could be completed by lesser-trained employees. The assembly line also brought the part to the builder rather than the other way around. In his book, *My Life and Work*, Ford shed light on the concept of waste by discussing how companies often have an inefficient layout for their machines and how people will habitually do something even though it is inefficient. Kaizen is the modern equivalent of how Ford rearranging the workplace for increased efficiency. Ford also pioneered the concept of standardization where a part from one vehicle will fit in the same space on an identical vehicle. Before standardization, every part was custom fit to each automobile which slowed the manufacture of each car and made them more difficult

to repair. Ford also explored waste reduction in other areas of manufacturing like ensuring that all the iron from the furnaces was used to create cars and none was left behind. (Ford, 2008)

Toyota Motor Corporation took over where Henry Ford left off with the Toyota Production System (TPS). TPS focused on increasing profits while cutting costs by eliminating waste. Some principles pioneered in the TPS are:

- The concept that production should adapt to market changes.
- Just-in-Time (JIT) manufacturing wherein parts are machined so they arrive at the next step exactly when they are needed. This prevents excessive stockpiling.
- The Kanban System which is used to ensure that material and products flow smoothly through a facility. This helps to reduce lead time and allows for smaller lot sizes.
- A standard operations routine which aims to make each production step take the same amount of cycle time.

With TPS, Toyota was able to improve their manufacturing process by increasing efficiency, reducing defects and waste, and increasing worker morale. (Monden, 1993, pp. 114)

Introduction to 5S

5S is a one of the most fundamental parts of Lean Manufacturing. It is also relatively straightforward to teach. This section discusses 5S in greater detail because it is the topic of our project's first module.

5S is a system used to help make production more efficient and cost-effective. The system involves 5 individual processes, or pillars. These pillars focus mainly on eliminating waste and creating a more organized workplace. Many companies use 5S as a primary means of improving efficiency. 5S is also one of the simplest ways to improve a manufacturing process because it forces the workspaces to be clean, organized, and free of clutter.

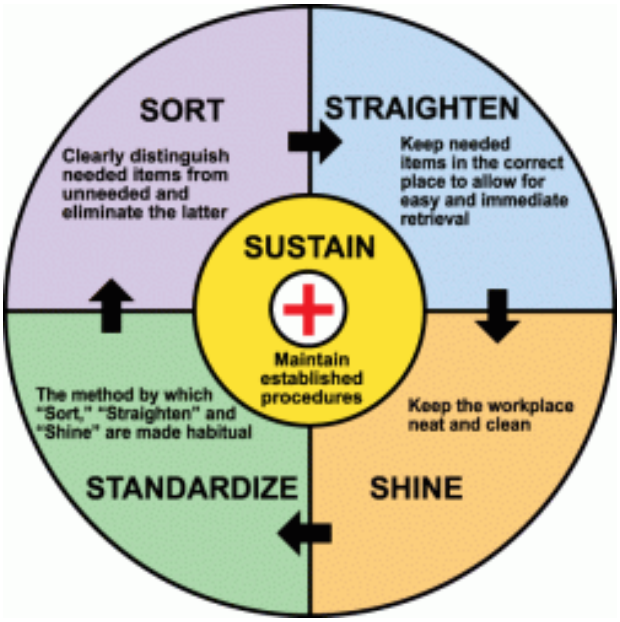


Figure 5- Flow Chart of 5S[7]

1. **Sort** (Seiri). It looks at an existing workplace and analyzes what tools, equipment, and material are required for a given production task. Anything that is not necessary is removed from the workspace. The primary benefit of sorting is a reduction in the required floor space for that production task. The Sort step in 5S also increases productivity by eliminating potential distractions like clutter.

2. **Set in Order** (Seiton). This pillar creates an efficient equipment layout so that workers can easily find tools and material needed for the process. This pillar also requires that the first pillar has already been completed and the area is free of unnecessary items. A popular tool for this pillar is the use of a shadow board to organize tools.

3. **Shine** (Seiso). It involves cleaning the workplace and keeping it clean. Once the area has been organized, it needs to be thoroughly cleaned and repaired. Then, everyday cleaning is required to maintain a high level of cleanliness and organization. The step Shine raises moral of workers because they are responsible for the cleanliness of their workspace and it is easier to work and be proud of the work they produce.

4. **Standardize** (Seiketsu). This pillar involves creating a consistent way to do every task so that they are done the same way every time. It also involves assigning people to maintain the first three S's. Some tools of standardizing are checklists, charts, and short meetings to ensure that jobs are being completed correctly.

[7] http://www.squidoo.com/lean5S?utm_source=google&utm_medium=imgres&utm_campaign=framebuster

5. **Sustain** (Shitsuke). It ensures that 5S practices are carried out all day, every day. This pillar is also critical in helping to change workers' mentality so they follow 5S practices in their daily routine.

The implementation of 5s is important to the manufacturing workplace because it enables the company to analyze their existing process and discuss ways to improve the process.

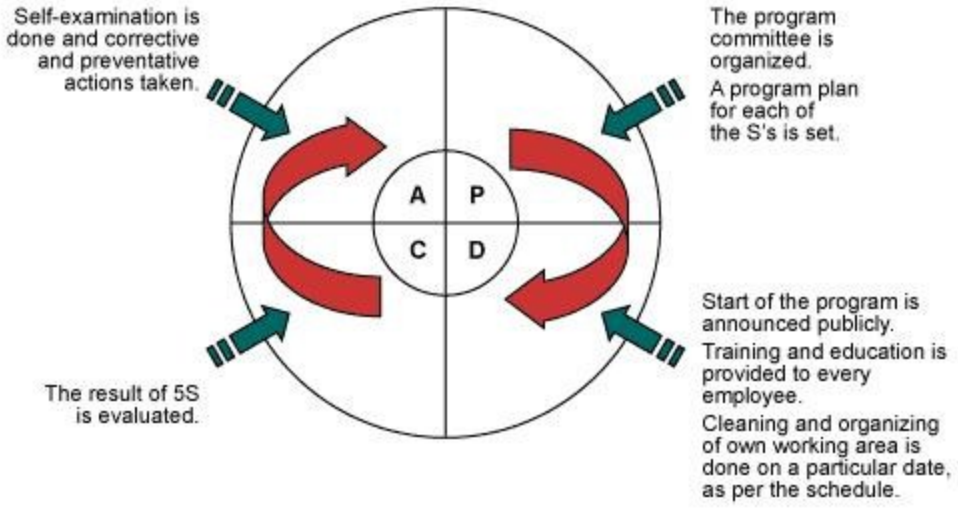


Figure 6- Implementation process of 5S[8]

It is imperative that the 5S's be maintained because if they are not, then the infrastructure of the process will fail and potentially cost the company money. One benefit of implementing 5S is that it reduces waste which in turn improves the efficiency of the process. Another benefit of 5S is it reduces the space that is required for storage is reduces. 5S also improves maintenance of the equipment and the appearance of the manufacturing floor, improves safety by removing clutter and items that are astray, and it also improves quality of the product along with the quality of work done by the employees. (Monden, 1993, pp. 199-219), (Hobbs, 2004, pp. 129-133)

[8] http://www.isixsigma.com/tools-templates/5s/practical-approach-successful-practice-5s/

Approach

Our approach to the project was as follows:

1. Design and Implement a survey to gauge high school teacher interest in certain topics
2. Research Lean Manufacturing Principles to determine what information could feasibly be included in teaching modules
3. Determine which media format to use for the module
4. Create the 5S Teaching Module
5. Test the 5S module
6. Edit the 5S Module to reflect feedback

Methods

Project Organization

The majority of this project was organized with a SharePoint account which allowed the project members and advisor to upload and edit documents and assign tasks while maintaining an adequate timeline.

Survey Creation and Implementation

The next step of the project was creating an effective survey. The purpose of the survey was to adequately gather information about our research topic. After the first draft was created, it was clear that it needed some editing. We researched how to create effective surveys using different educational resources from Keene State and Colorado State Universities. We were able to use these sources to create a successful survey that was easy to follow. For example, the general consensus from all three sources was to order the questions in such a fashion so as to avoid biased opinions by putting sensitive questions at the end of the survey. Another key piece of information we took from the documents was not to make the survey too long because if there are too many questions in the survey, the participants would be less likely to finish it.

In order to improve the rough draft of the survey, we removed the first question because it involved potentially sensitive material that was not relevant to the scope of our project. Then we to provided survey participants with more detailed answers to our survey questions so we could gather more detailed information than "yes or no" questions could provide. We also wanted to determine why certain principles were covered in the classroom while other topics were neglected, along with what topics the teachers would prefer to have material for. This would allow us to develop the teaching modules in accordance with what teachers want or need. Another piece of information we asked for was what teaching medium (PowerPoint, videos, pictures, etc.) teachers preferred and whether or not they would use such a resource. Our last change was to give participants the option to us by using a Worcester Polytechnic Institute mailing list called lean@wpi.edu. Both the rough and final drafts of the survey can be found in the appendix section of this paper.

When the survey was edited and reviewed by Professor Bergstrom, we sent the survey and its intent to the Institutional Review Board (IRB). The purpose of the IRB review process is to make sure that our questions do not endanger survey participants by asking personal or private information. The forms required to submit a survey to the IRB are found in the appendix. These forms are available on the WPI website (www.wpi.edu) in the *Offices and Services* section. After the survey was sent to the IRB (irb@wpi.edu) a reply was sent to all of the authenticated users on the project, stating that the survey was approved and we were free to send the survey out to the participants which can also be found in the appendix section.

After the review process from the IRB was completed successfully, the survey was sent out to high school machine tool technology teachers along with a paragraph about what it is we are trying to accomplish. However, the survey was not as successful as hoped and only received a few views due to logistical complications. Therefore, we decided to come up with a backup plan. After discussing options with Professor Bergstrom, we decided that a teaching module covering 5S would be a good place to start because most industries use 5S principles.

Lean Manufacturing Research

We researched Lean Manufacturing Principles to gain the necessary level of knowledge to create the Introduction to Lean Manufacturing Section of this paper. We then further researched 5S principles in order to create the 5S Teaching Module.

5S Teaching Module Creation

We then needed to determine what form of media would most effectively convey our message to the students. We were considering using a teaching tool called ASSISTments to create an online course. Based on personal experience with high school technology students, we decided not to use ASSISTments because it was not interactive enough and some schools might not have the necessary number of computers to facilitate such a product. As such, we determined that using a PowerPoint presentation in combination with interactive classroom activities would be the best way to teach a class because it allows for a single teacher to present to an entire class and the material will keep students' attention.

We created an outline and a basic template for the module in the form of a PowerPoint presentation. This presentation gives a brief overview of 5S and then details each 5S pillar. We also included a short video for each section. After each video, we show picture examples of how each pillar can be used. Then we ask 2-3 short questions for each pillar. These questions provide a comprehensive review of the important points for each pillar. The module is designed to give a basic understanding of 5S principles upon which students can build during their careers. This way, students will at least be familiar with 5S when they apply for a job after high school

In addition to the teaching module outline, we also included a teacher copy of the outline which includes some additional information and the answers. The proctor copy also details how an instructor should go about teaching the module. For example, we suggest that teachers bring their students into their shop and actually apply the 5S principles. By applying the principles from the module, students will be more likely to retain information.

We considered suggesting that teachers demonstrate each 5S pillar immediately after its respective slides, but we decided that it would be more effective to demonstrate all of the pillars at once after the module. Our rationale for this decision was that moving an entire class of students could take several minutes, and moving the class multiple times within a class period would only waste time. We designed the module to take about 30-40 minutes and then a demonstration of 5S could take up to an hour or more at the teacher's discretion.

There were several important factors we had to keep in mind when creating the module. The first was the module's audience. Because it is geared towards technical high school students, we had to make sure that the material difficulty was such that high school students who may or may not be academically strong could understand without becoming too elementary. We also had to note that 5S principles are applied very differently at every shop. Therefore, we could not include a specific floor plan because it would not be directly applicable to the students' shops.

We created two versions of the PowerPoint. The first version includes links to the YouTube videos and the second version has the videos embedded. The video quality of the embedded videos is not as good as the YouTube videos due to conversion and compression, so we recommend that teachers use the first version if a good internet connection is available.

The videos we used were all produced by a company called Manufacturing Skills Australia (MSA). We chose to use their videos because the presentation format was clear, consistent, and concise. MSA works to develop training for Australian manufacturers on a wide variety of topics.[9]

[9] MSA's website is http://www.mskills.com.au/Default.aspx

5S Teaching Module Testing

We decided to test the 5S Teaching Module several times in order to receive feedback on its effectiveness. The first test was conducted at Chicopee Comprehensive High School (CCHS). One of the group members presented the module to the students and teachers at CCHS. After the presentation, we were able to obtain feedback which was then useful for improving the module's quality.

We also sent a copy of the module and proctor copy to a contact at a local manufacturing firm for review, and we received positive feedback. A copy of a presentation they use was also sent to us to use for comparison.

We presented the module to college students in a machining class for feedback. We showed the presentation as we intend it to be utilized as well as a question and answer session at the end of the module presentation.

Results

Survey

The survey experienced logistical issues and did not produce any feedback. Therefore, it was not a valid tool for determining what topics to include in the teaching module. Based on research and a discussion with our advisor, we determined that 5S was a universal part of Lean Manufacturing. Therefore, we decided to make a module covering 5S.

Chicopee Comprehensive High School Feedback

The module was piloted and presented to Chicopee Comprehensive High School. We were able to take the feedback from the pilot and determine what changes needed to be made to the module to further develop the product. The feedback from Chicopee Comprehensive was to add more before and after pictures. Therefore, we added more interactive questions and activities along with the existing pictures. Another suggestion was to make the presentation

flow better, so we added animations to hide the answers and to better allow for discussions. The proctor copy document cues the teacher or professor to bring up certain points and open up a discussion.

Local Manufacturing Firm Feedback

We sent the module and proctor copy to a contact a local manufacturing firm for review and feedback. They informed us that the presentation was exceptional and the proctor copy was a useful tool in the presentation. They also sent along a PowerPoint presentation that is used in their training program. Unfortunately, they requested that we did not disclose the name of the company or the name of the company that developed the sample presentation.

College-Level Manufacturing Class Feedback

We presented the module to the class and ended the presentation with a discussion. Some of the feedback we received was to fix the animations in the presentation to make the multiple choice questions appear with the answers and highlight the answers and maybe discuss other implementations of 5S. Additionally we were able to discover other minor issues with the module like some links to the videos were not hyperlinked and the last video cut out early.

Discussion

Logistical Issues with Survey

When we sent the survey out, it first went to our advisor. He then sent it out to a connection that we were told would send it to all high schools that used HAAS technology. Unfortunately, due to some lack of communication, the survey did not get sent out to the intended participants. To address this unexpected issue, we had to determine which topic we wanted to go into depth about. After analyzing basic lean manufacturing topics, it was decided that 5S visual management was the most beneficial topic to go into depth on because it is a relatively simple tool that is used in almost every industry and school and it is an easy topic to illustrate with classroom exercises.

5S Teaching Module Development

After dealing with logistical issues with the survey, an interactive module on 5S visual management was created. This module included information about 5S as a whole and each step of 5S and how it can be implemented on the machine shop floor. For example, the Sort section of the module gives information and presents a video on what Sort is and how industry uses this step. At the end of the Sort section there is a quiz that measures if the students retained the information. There is also a series of pictures that represent before and after the sorting process was initiated. This format is consistent throughout each of the 5 steps of 5S. At the end of the entire module there is an activity that allows for the students to go out to their work station and analyze and implement the different steps of 5S. This activity allows for the students to visualize what each step accomplishes and how it affects their work. The students are then encouraged to share their findings and suggest ways to fix the problems they may have encountered at their work station.

5S Module Proctor Copy Development

After the teaching module was developed, we felt it would be beneficial to create a document that would be able to be utilized by the teacher to aid in presenting this module. The purpose of this document was to make the presentation easy to give and the person giving the presentation did not have to necessarily know everything about 5S visual management.

The document walks the teacher through the presentation slide by slide and also guides them into discussions and interactive activities. For example, some of the questions can have more than one answer and this document guides the teacher into discussions about other answers or topics and examples that should be covered. These topics are in this document instead of being right in the presentation because it makes the presentation easier to understand and prevents the teacher from just reading the slides.

5S Teaching Module Testing and Feedback

Over Christmas break, the module and the proctor material was presented to the machine tool technology students and teachers at Chicopee Comprehensive High School. The presentation was successful but there were some complications with the presentation. Because we are presenting this material to students between the ages of fourteen and eighteen it was difficult to maintain the student's attention and concentration. With the interactive questions, videos, and activities, the students were able to keep their attention for most of the presentation. The questions and discussion points helped maintain the student's attention because they felt as if they were actually part of the presentation instead of being lectured at. In the beginning of this project, we speculated that it would be difficult to keep students interested, and we designed a product to accompany young students. At the end of the presentation we asked the students and teachers for feedback. The main feedback we received to have more discussions and to add animations to the slides to allow for the presentation to flow smooth.

5S Teaching Module Revision

We were able to take the feedback from the pilot program and redesign the module to better accommodate the desires of the students and teachers. This project allowed us to take an idea, research a topic, and develop sufficient teaching material that is appropriate for a younger audience. We were able to implement a full manufacturing process to develop the finished product: Brainstorm an Idea, Draft the product, Pilot the product, re-Draft the product, Pilot the product again, and create a finished product.

Project Continuation

We hope that our IQP is just the first step in a recurring IQP here at WPI. As such, we have some ideas and suggestions for continuing this project in the coming years.

We would suggest creating an Introduction to Lean Manufacturing module next. Such a module would explain what lean manufacturing is and why it is important to the industry. The module should contain an overview of lean manufacturing origins, tools, and basic examples of how each technique is used. Some potential tools to include are discussed in the Introduction

to Lean Manufacturing section of this paper. Subsequent modules would cover one or more of these tools in greater detail in a fashion similar to the 5S module presented in this paper.

A future group could then compile all of the modules into comprehensive Lean Manufacturing course. The course and modules could then be put into a free online database where teachers can access them and use them to teach their students. Future groups may want to include students knowledgeable in web design to create this database.

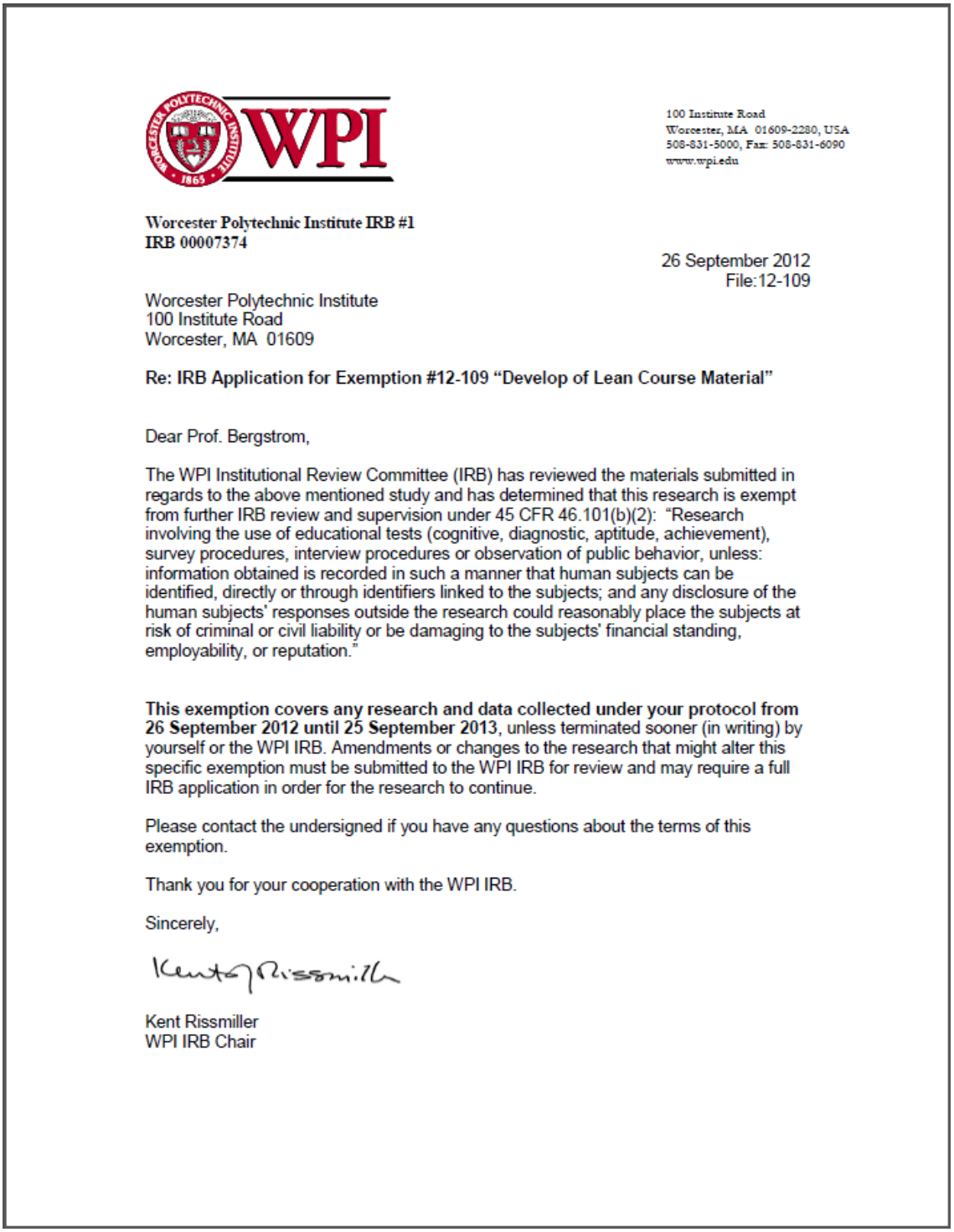
Conclusions

We:

- Were presented with logistical issues and dealt with them accordingly.
- Developed a teaching module on 5S Visual Management
- Developed supplemental teaching materials for teachers
- Piloted the module and supplemental material at Chicopee Comprehensive High School and a college-level manufacturing class
- Implemented the feedback from the pilot sessions in order to improve the teaching module
- Determined that this project can be continued to present more lean manufacturing tools and to create a database with all of these documents online

Appendix

IRB Information



100 Institute Road
Worcester, MA 01609-2280, USA
508-831-5000, Fax: 508-831-6090
www.wpi.edu

Worcester Polytechnic Institute IRB #1
IRB 00007374

26 September 2012
File:12-109

Worcester Polytechnic Institute
100 Institute Road
Worcester, MA 01609

Re: IRB Application for Exemption #12-109 "Develop of Lean Course Material"

Dear Prof. Bergstrom,

The WPI Institutional Review Committee (IRB) has reviewed the materials submitted in regards to the above mentioned study and has determined that this research is exempt from further IRB review and supervision under 45 CFR 46.101(b)(2): "Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation."

This exemption covers any research and data collected under your protocol from 26 September 2012 until 25 September 2013, unless terminated sooner (in writing) by yourself or the WPI IRB. Amendments or changes to the research that might alter this specific exemption must be submitted to the WPI IRB for review and may require a full IRB application in order for the research to continue.

Please contact the undersigned if you have any questions about the terms of this exemption.

Thank you for your cooperation with the WPI IRB.

Sincerely,

Kent Rissmiller
WPI IRB Chair

Figure 7-IRB Approval Form

WORCESTER POLYTECHNIC INSTITUTE
Institutional Review Board
Application for Exemption from IRB Review for
Survey or Interview Research Involving Minimal or No Risk

WPI IRB use only
IRB #
Date:

This application is specifically intended for projects in which students are expected to conduct interviews, surveys or focus groups. *Use of this application is recommended for most student project research involving minimal risk. Proposed research meets the definition of "minimal risk" when the risks to research subjects are not greater than those ordinarily encountered in daily life.*

RESET FORM

Project Faculty Advisor(s):

Name: Tel No: E-Mail Address:

Department:

Name: Tel No: E-Mail Address:

Department:

Project Faculty Instructor:

Name: Tel No: E-Mail Address:

Department:

Student Investigator(s): *ALL student investigators must be listed.*

Name: Tel No: E-Mail Address:

Name: Tel No: E-Mail Address:

Name: Tel No: E-Mail Address:

Name: Tel No: E-Mail Address:

Name: Tel No: E-Mail Address:

Project Title:

Project Location and Time Frame:

Page 1

Figure 8-IRB Application Form, page 1[10]

[10] Form can be found at:

http://www.wpi.edu/Images/CMS/IRB/Application_for_Exemption_from_IRB_Review_for_Survey_or_Interview-3-2011.pdf

WPI IRB Application for Exemption from IRB Review for Survey or Interview Research Involving Minimal or No Risk

Expected Research Subjects: (e.g. museum visitors under the age of 12)

Project Mission Statement and Objectives

Brief Methods Listing: (e.g. "Survey of public to ascertain knowledge and opinions about climate change" or "Interviews of professionals working on climate change regarding effective city climate change program")

Appendix 1: Attach the draft methodology chapter or statement of research methods.

Appendix 2: Attach a draft of surveys and/or a list of questions to be used for interviews or focus groups. If sample questions are included in Appendix 1, Methodology Chapter, indicate page numbers here.

1. Is the proposed research sponsored or supported by a US federal agency or by US government funding? If so, identify sources. No ☐ Yes ☐
2. Is the proposed research funded by a corporation or foundation? If so, identify sources. No ☐ Yes ☐
3. Does the proposed research involve vulnerable research subjects? (e.g. children, prisoners, students, persons with mental or physical disabilities, pregnant women) No ☐ Yes ☐
4. Does the research involve human subjects in ways other than as participants in interviews, focus groups, or surveys? (e.g. observation of public behavior, use of archived data or experimental procedures) If yes, explain. No ☐ Yes ☐
5. Will the researchers collect information that can be used to identify the subjects? No ☐ Yes ☐
6. Could the disclosure of a human subject's identity and responses place the subject at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability or reputation? No ☐ Yes ☐
7. Will the researchers disclose the identity or the individual responses of any human subjects? (e.g. by quoting an individual, whether or not identified by name or title) No ☐ Yes ☐

Page 2

Figure 9-IRB Application Form, page 2

WPI IRB Application for Exemption from IRB Review for Survey or Interview Research Involving Minimal or No Risk

IF you answered yes to question 6 or 7, answer these questions:

A. What is the potential risk to human subjects?

B. How will you eliminate or reduce said risk to an acceptable level?

Please Print Form Before Signing Below

By signing below, all participants in this research project are agreeing to abide by the following instructions:

1. You agree to inform subjects orally or in writing that:
   - Participation in the research is voluntary.
   - Participants may end their participation at any time.
   - Participants need not answer every question in an interview or survey.

2. If your research is **anonymous**, you also inform subjects that you are not collecting names or any identifying information from them.

3. If your research is **confidential**, you inform subjects that no identifying information will be disclosed with individual responses.

4. If your research is **NOT** completely anonymous and confidential, you must obtain each subject's permission to publicly disclose his or her identity and/or responses. All requests for anonymity and confidentiality must be honored. The subject must be offered the opportunity to pre-approve the publication of any quoted material

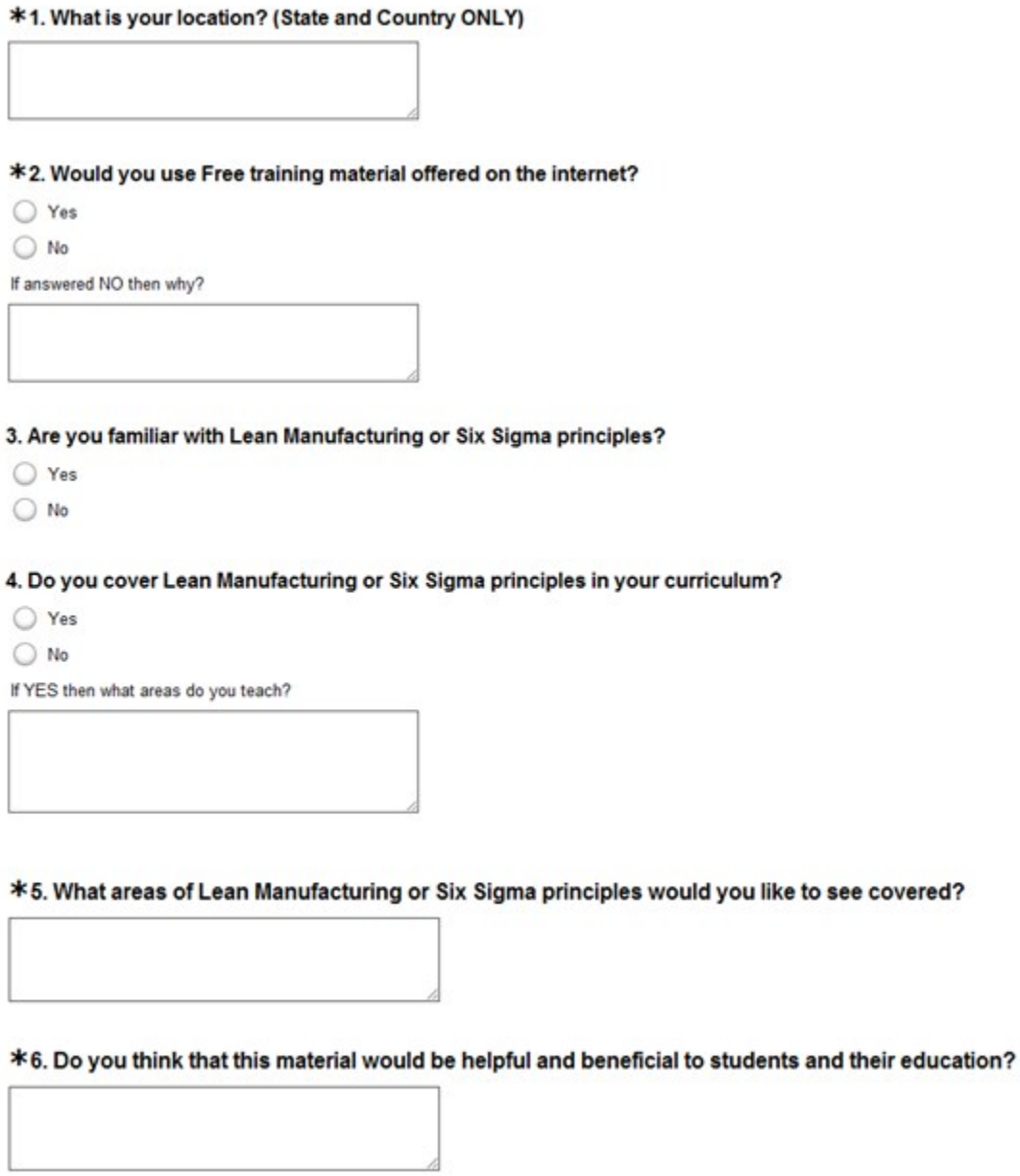
Signature of Faculty Advisor _____ Date _____

Print Full Name and Title _____

Please return a signed hard or electronic copy of this application to the WPI IRB c/o Ruth McKeogh, 2nd floor Project Center or irb@wpi.edu.
If you have any questions, please call (508) 831-6699.

Figure 10-IRB Application Form, page 3

Survey Drafts



*1. What is your location? (State and Country ONLY)

*2. Would you use Free training material offered on the internet?

Yes

No

If answered NO then why?

3. Are you familiar with Lean Manufacturing or Six Sigma principles?

Yes

No

4. Do you cover Lean Manufacturing or Six Sigma principles in your curriculum?

Yes

No

If YES then what areas do you teach?

*5. What areas of Lean Manufacturing or Six Sigma principles would you like to see covered?

*6. Do you think that this material would be helpful and beneficial to students and their education?

Figure 11-Survey Rough Draft

1. Do you currently teach Lean Manufacturing Principles?

- ○ Yes
- ○ No

2. If you do not currently teach Lean Manufacturing Principles, why? Select all that apply.

- ☐ N/A...You do teach Lean Manufacturing Principles.
- ☐ Lean Manufacturing Principles are not required in your curriculum.
- ☐ You have not been trained in Lean Manufacturing Principles.
- ☐ You do not have the time to cover Lean Manufacturing Principles.
- ☐ You do not have the material/resources to cover Lean Manufacturing Principles
- ☐ Other (please specify)

3. Select all Lean Manufacturing Principles you currently teach or would like to see included in your curriculum.

- ☐ 5S
- ☐ Six Sigma
- ☐ Total Quality Management
- ☐ Kanban
- ☐ Poka Yoke

Other (please specify)

4. Would you use free online resources to help teach Lean Manufacturing Principles in your classes?

- ○ Yes
- ○ No

If not, then why?

5. Which resources, if any, would you use to help teach Lean Manufacturing Principles?

- ☐ PowerPoint or equivalent slideshows covering Lean Manufacturing Principles.
- ☐ Tests/quizzes to evaluate students' knowledge level on Lean Manufacturing Principles.
- ☐ Visuals demonstrating Lean Manufacturing Principles in action.
- ☐ Links to additional information
- ☐ Online resources would not be helpful for teaching Lean Manufacturing Principles.

Other (please specify)

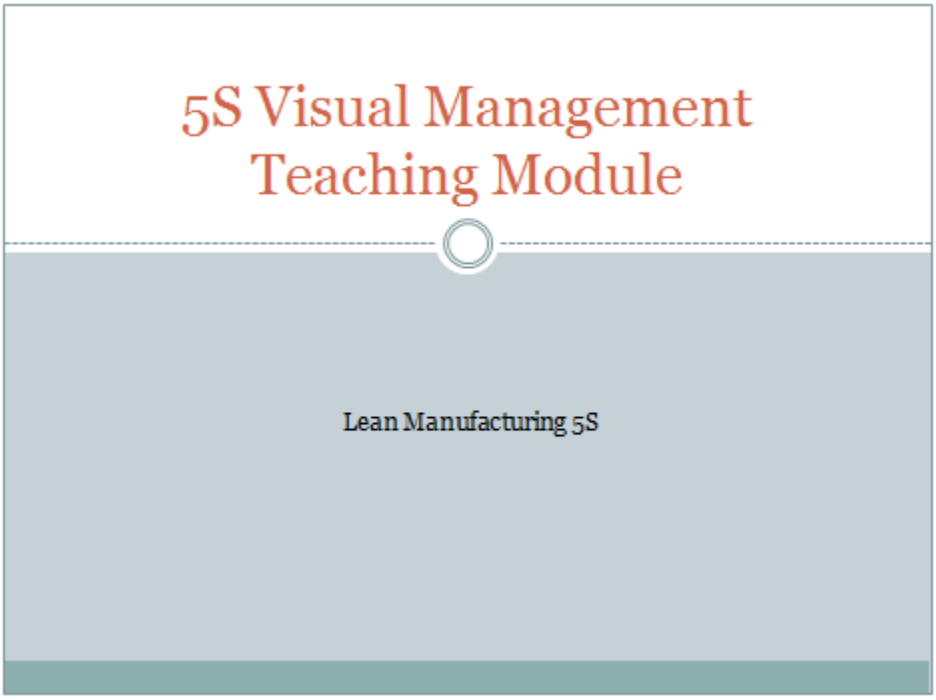
6. If you are teaching Lean Manufacturing principles, please take a moment to describe the teaching material.

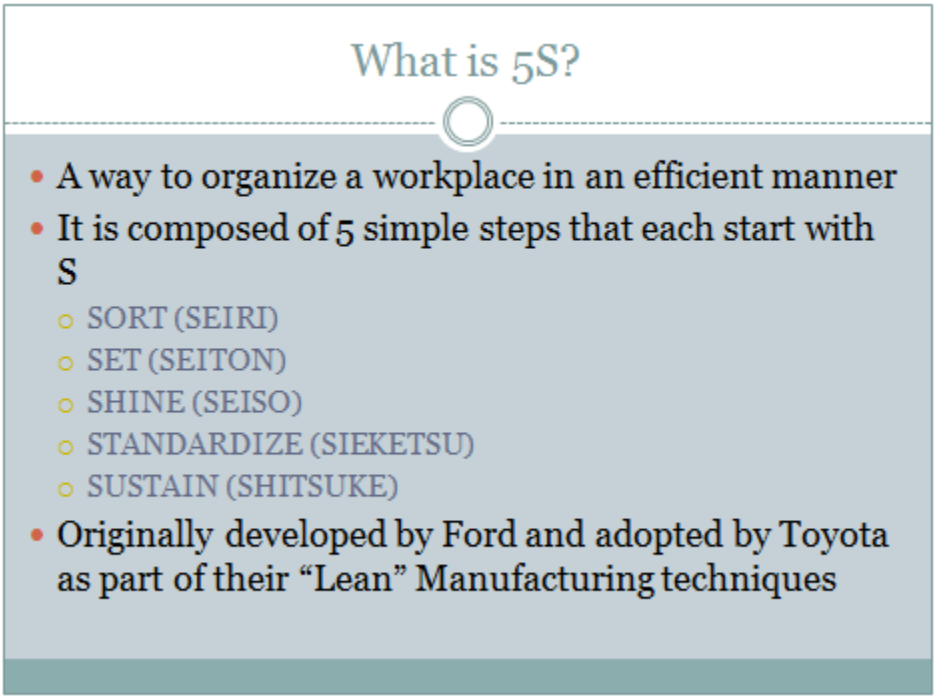
If you wish to recieve updates and more information, please contact us at ---------- lean@wpi.edu

Figure 12-Final Survey

5S Teaching Module and Proctor Copy

Module





Introduction to 5S

- Please watch the following Video
  - http://www.youtube.com/watch?v=OACMvw6G4Lg&feature=plcp

Questions on the Introduction to 5S

- What are the 5 S's of 5S?
  - Sort, Set, Shine, Standardize, Sustain
- What is an optional sixth S? put at end
  - A. Safety
  - B. Strain
  - C. Satisfy

Sort

- Evaluate what tools are necessary for production
- Eliminate all of the unnecessary equipment and parts
- Prioritize required tools and equipment by usage

Sort

- Please watch the following video:
  - http://www.youtube.com/watch?v=s2xqBMdKjGo&feature=relmfu

Questions

- What does Sort look at in the workplace?
  - Sort looks at an existing workplace and analyzes what tools, equipment, and material are required for a given production task.
- What is the primary benefit of Sort?
  - Primary benefit is the reduction of unnecessary material on the production floor

Make some suggestions for improvement by Sorting

After Sorting

Set

- Arrange the necessary tools in a way that they are easily accessible
- Prioritizes tools by usage allowing the most used tools readily available.
- Could also be called Straightening

Shadow boards are a good example of Set

Set

- Please watch the following video:
  - http://www.youtube.com/watch?v=i5bPmXr2yGs&feature=relmfu

Questions

- What is a good example of Set?
  a) Shadow Board
  b) Tape outlines
  c) Removing unnecessary material
  d) A and B
- How should tools be prioritized?
  - Tools should be organized in an ergonomic fashion.

Make some suggestions for improvement by Setting

After Setting

Shine

- Make sure that all of the equipment is clean and well organized.
- Repair anything within the workplace that needs repair.
- At the end of each shift, make it a task to clean your workspace.
- Could also be known as Sweeping.

Shine

- Please watch the following video on Shine:
  - http://www.youtube.com/watch?v=B1j8jK9dE6Y&feature=relmfu

Questions

- Shine or shining can also be known as what?
  a) Swiping
  b) Sweeping
  c) Sustain
- What does Shine involve?
  - The involvement of cleaning the workplace and repairing any equipment that needs repair.

Make some suggestions for improvement by Shining

After Shining

Standardize

- Make sure that all work stations that do the same job are identical
- Everyone that is responsible for the same job should be able to work at any station
- Some tools of standardizing are checklists, charts, and short meetings.
- Involves assigning people to maintain the first three S's

Standardize

- Please watch the following video on Standardize:
  - http://www.youtube.com/watch?v=r3cYjjEt3UM

Questions

- Standardize ensures that all works stations are _____?
  a) Different
  b) Identical
  c) Similar
  d) Personalized
- Identify tools used to implement Standardizing?
  - The use of checklists, charts, and small meetings

Sustain

- Maintain the developed standard work practices
- Sustain is critical in changing the workers' mentality so they follow 5S practices in their daily routine
- Sustain ensure that 5S practices are carried out all day and everyday

Sustain

- Please watch the following video on Sustain:
  - http://www.youtube.com/watch?v=8ZbXG3Hbt4w&feature=relmfu

Questions

- What is critical about the pillar Sustain?
  - Sustain is critical in changing the workers' mentality so the follow 5S practices
- In brief what does Sustain do for the 5S system?
  - Sustain allows 5S to work, it ensures that workers' follow the 5S system and makes sure this system thrives day in and day out.

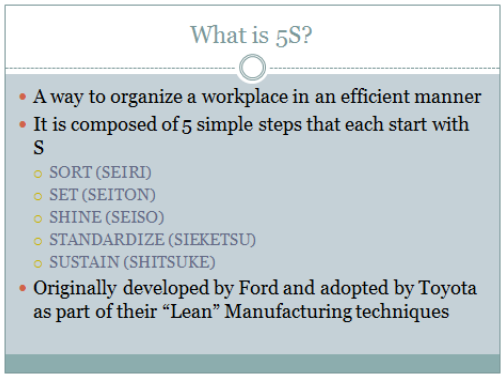
Quiz Time

1. On a piece of paper write down the 5S's and why they are important.
2. You are a shop manager, Create a check list for your employees using this information to evaluate their workspace to make sure they are implementing 5S.

Proctor Copy

Learning Objective for this module: Be able to convey the aspects of 5S to a group of students and have them understand how to implement the steps in their learning environment.

Slide 2: What is 5S?



A way to organize a workplace in an efficient manner

Speaking point: 5S can be used in any business to improve efficiency and productivity. It is a good way to evaluate current processes and eliminate wasted time and materials. It also enables problems to be recognized, evaluated, and fixed easily and in a timely manner.

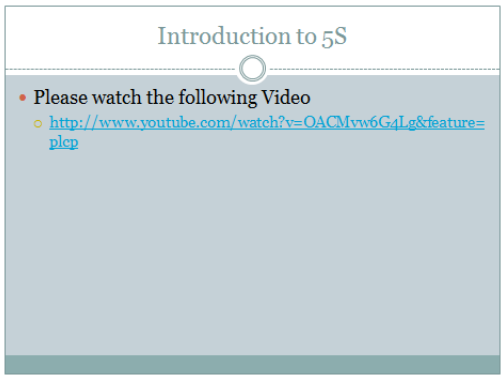
Speaking Point: The translations are not exact, so some words may vary, but they mean the same thing. For example you may encounter straightening instead of setting

- It is composed of 5 simple steps that each start with S
  - SORT (SEIRI)
  - SET (SEITON)
  - SHINE (SEISO)
  - STANDARDIZE (SIEKETSU)
  - SUSTAIN (SHITSUKE)

- Originally developed by Henry Ford and then it was adopted by Toyota as part of their "Lean" Manufacturing techniques

Speaking Point: Talk about how Henry Ford was one of the first to develop the assembly line and the technology was then adapted by Toyota and implemented into their manufacturing process

Slide 3

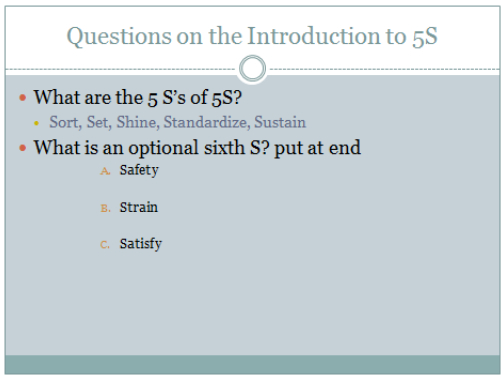


Have students watch a video on an introduction to 5S: after video

Speaking Point: Ask the Class for suggestions on "What Kind of waste does 5S remove"? It removes unnecessary tools and material while reducing production time.

In Industry time = money, the less time it takes for a process to be completed the more money the company makes and vice versa.

Slide 4



Introduction Questions

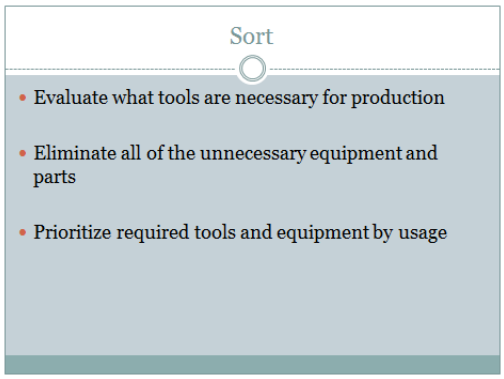
What are the 5S's?

Sort, Set, Shine, Standardize, Sustain

What is an optional sixth S?

Safety: Talk about why safety is important in a shop environment.

Slide 5

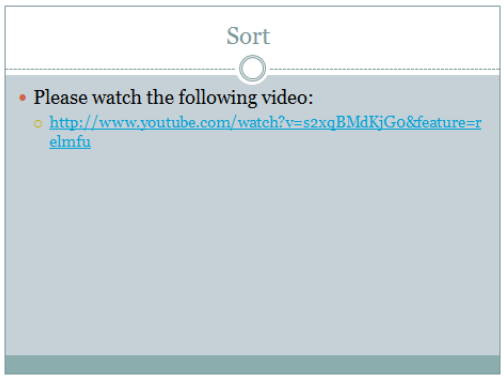


Sort

- Evaluate what tools are necessary for production. You look at your personal work station and analyze what is there and what is missing. Along with what is not necessary.
- Eliminate all of the unnecessary equipment and parts. After looking at your work station decide what is absolutely necessary and eliminate the unnecessary tools or material into storage.
- Prioritize required tools and equipment by usage. When organizing tool boxes or work benches, take what tool or material is used the most and that tool is put the closest to you. Each tool should be placed within reach accordingly.

Give an example: Suggest or ask the class what tools and materials that would be necessary at a work station to complete a job, maybe provide them with a print and ask them to analyze what tools and materials and fixturing that would be needed for the job.

Slide 6



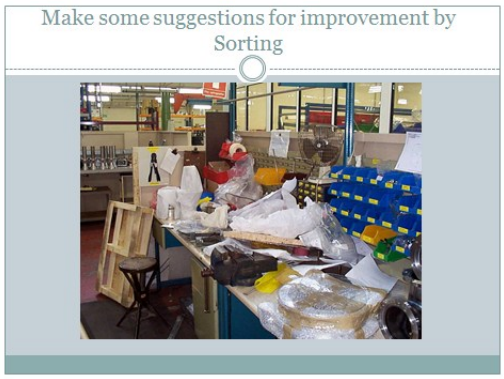
Sort Video

Slide 7

Sort Questions

- What does Sort look at in the workplace?
  - Sort looks at an existing workplace and analyzes what tools, equipment, and material are required for a given production task.
- What is the primary benefit of Sort?
  - Primary benefit is the reduction of unnecessary material on the production floor. Bring up why having unnecessary material on the shop floor is detrimental to production.

Slide 8

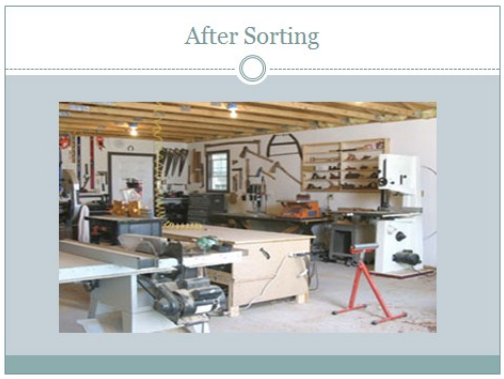


There is a picture on this slide and the teacher should ask the class to make some suggestions on how to improve this scenario.

Some points that can be brought up are:

- Get rid of trash that is on the work bench
- Remove obstacles that are on the floor (skid)
- Put newly received material or tools where they belong

Slide 9



This is a picture of what a shop or workplace should look like

Slide 10

SET

Arrange the necessary tools in a way that they are easily accessible

- Ask the class what the importance of this- by making tools and materials more accessible it cuts back on the time that an employee or student takes looking for a tool, this makes the production time shorter which in turn increases the value of the product.

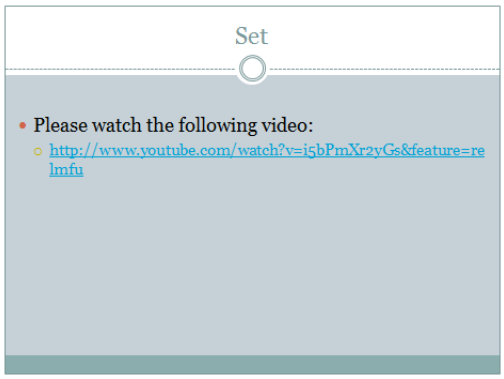
Prioritizes tools by usage allowing the most used tools readily available

- This is important from an ergonomic standpoint: by having the tools that are used most often right at hand it decreases the amount of bending and reaching that the employee or student will have to do for the job.

Could also be called Straightening

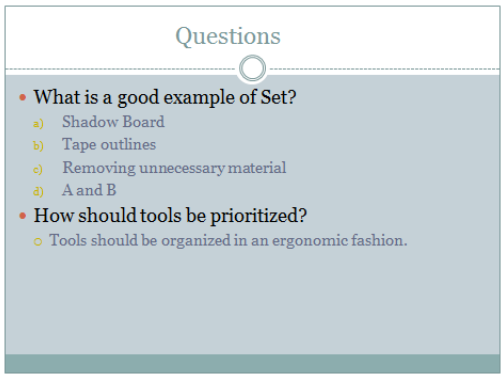
Additional comment: Shadow boards are commonly used across shops and industries and even offices. A shadow board is something that has the outline, shadow, or label of the tool that belongs in that spot. These can also be cut outs in foam that fit inside of a drawer to hold tools.

Slide 11



Video on SET

Slide 12

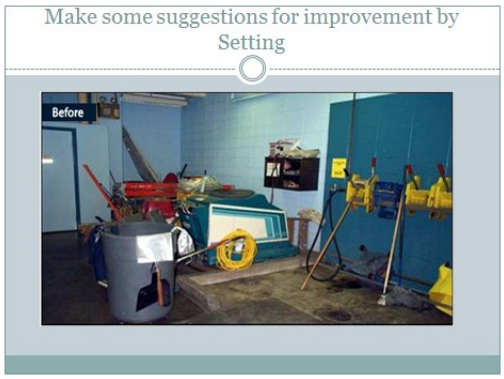


Questions on Set

- What is a good example of Set?
    a) Shadow Board
    b) Tape outlines
    c) Removing unnecessary material
    d) A and B

- How should tools be prioritized?
    Tools should be organized in an ergonomic fashion. Or they are organized in a fashion that allows for the most used tools to be easily accessed.

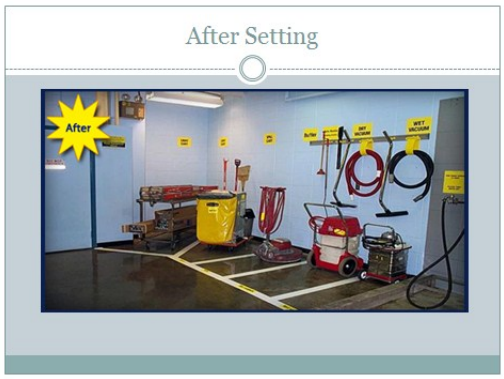
Slide 13



Have the class offer suggestions for this picture:

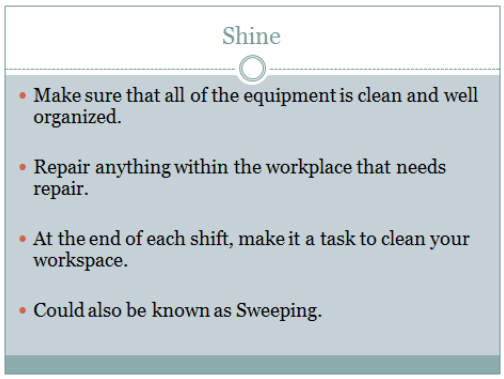
- Make specific places for each item.
- Use tape to section off parts of the shop for each item.
- None of these items are easily accessible.

Slide 14



Picture of After Setting

Slide 15



SHINE

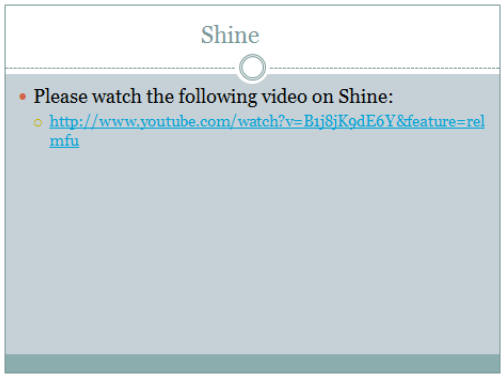
- Make sure that all of the equipment is clean and well organized.
    - This is important not only for the presentation of the shop, but for the maintenance of the equipment. This makes for repairs to be easy because the equipment won't have to be cleaned in order to be repaired and the equipment will last longer this way as well.

- Repair anything within the workplace that needs repair.
    - Making little repairs/ maintenance will extend the lifetime of a piece of equipment or tool.

- At the end of each shift, make it a task to clean your workspace.
    - This is also important because it enforces that the tools and equipment you utilize at work is your own and you would not want to come into work with your workstation a mess.

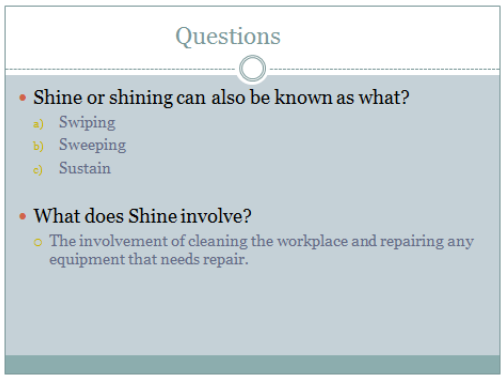
- Could also be known as Sweeping

Slide 16



Video

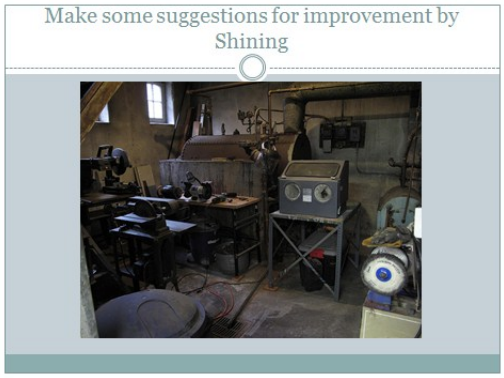
Slide 17



Questions have the students answer the questions as a class.

- Shine or shining can also be known as what?
    a) Swiping
    b) Sweeping
    c) Sustain
- What does Shine involve?
    - The involvement of cleaning the workplace and repairing any equipment that needs repair.

Slide 18

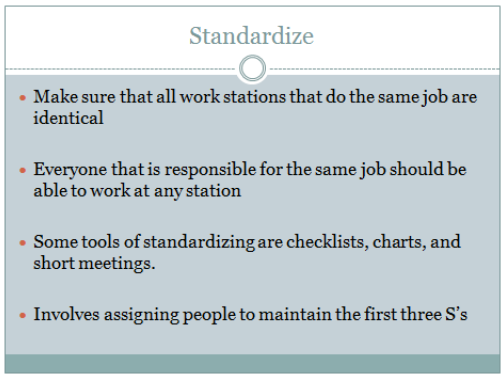


Picture

Slide 19

Picture

Slide 20



STANDARDIZE

Make sure that all work stations that do the same job are identical.

- This will enable anyone who does that one task to use your bench and know where every tool is.

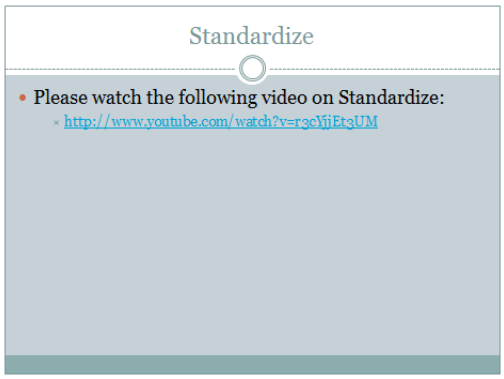
Everyone that is responsible for the same job should be able to work at any station

- This eliminates confusion if a student or employee is re-located to a different area. Also if a work station is shut down for maintenance or repairs the employee or student will be able to continue his or her work.

Some tools of standardizing are checklists, charts, and short meetings.

Involves assigning people to maintain the first three S's

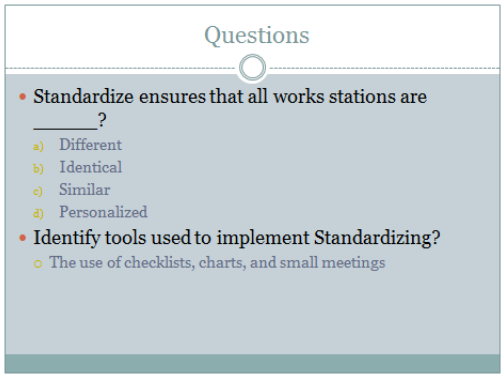
Slide 21



Video

For some reason this video has been cut short. The video still represents what Standardize entails in the 5S process.

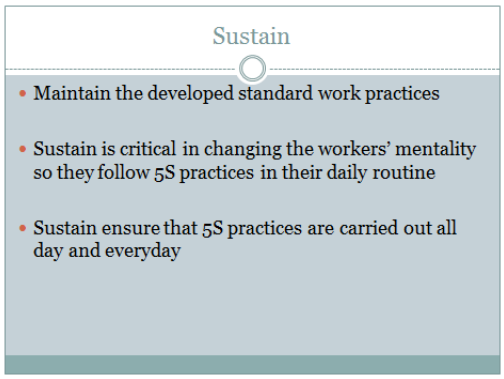
Slide 22



Questions

- Standardize ensures that all works stations are _____?
    a) Different
    b) Identical
    c) Similar
    d) Personalized
- Identify tools used to implement Standardizing?
    a) The use of checklists, charts, and small meetings

Slide 23



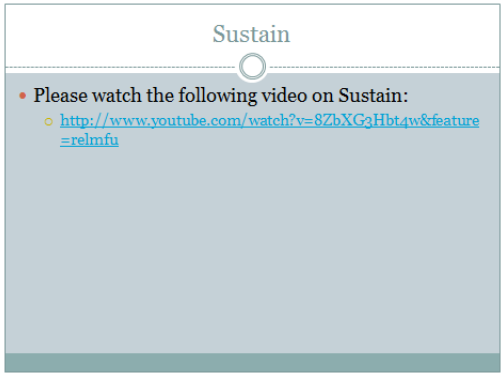
Sustain

Maintain the developed standard work practices

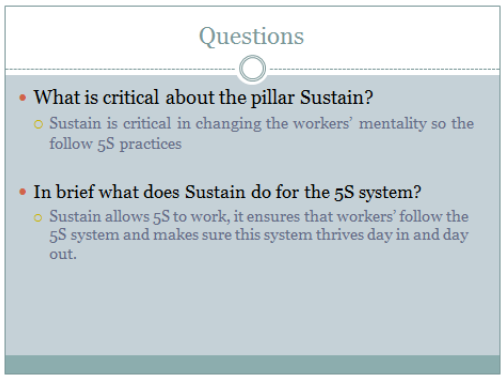
Sustain is critical in changing the workers' mentality so they follow 5S practices in their daily routine

Sustain ensure that 5S practices are carried out all day and everyday

Slide 24



Slide 25



Questions

What is critical about the pillar Sustain?

Sustain is critical in changing the workers' mentality so the follow 5S practices.

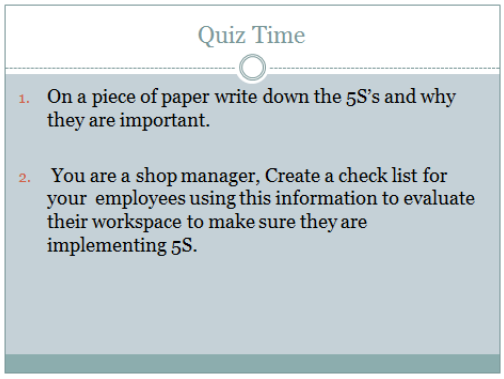
- Talk about how it may be hard to implement new ideas because people are accustomed to the old way and don't think it needs to change.

In brief what does Sustain do for the 5S system?

Sustain allows 5S to work, it ensures that workers' follow the 5S system and makes sure this system thrives day in and day out.

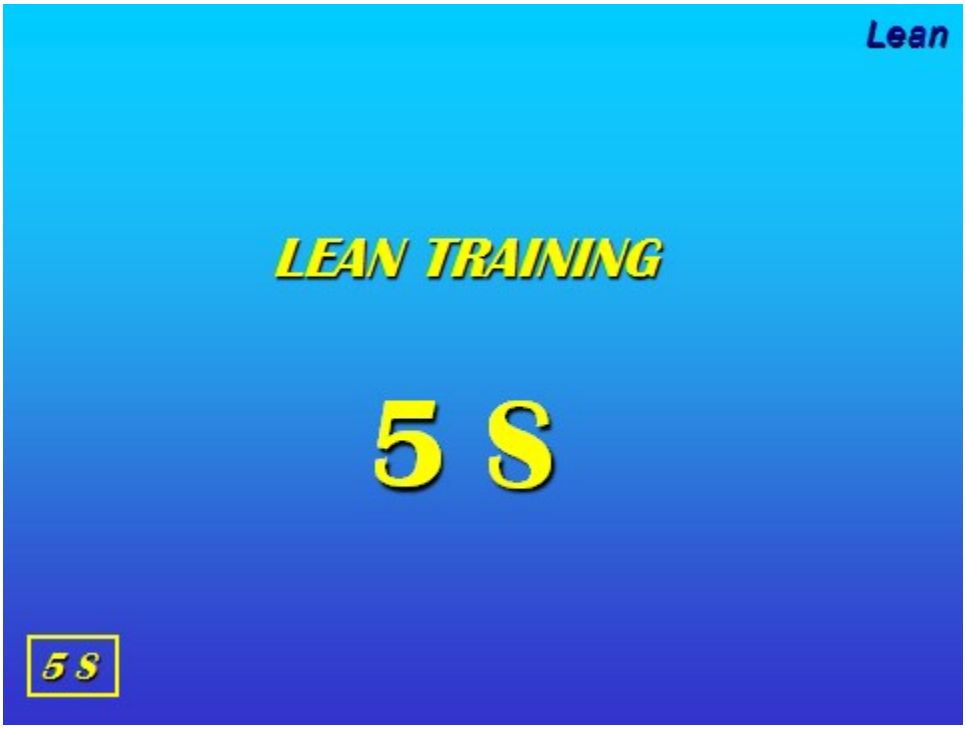
- This is probably the most important aspect of 5s because if you don't sustain then all of the work you did in the other steps will be lost and useless.

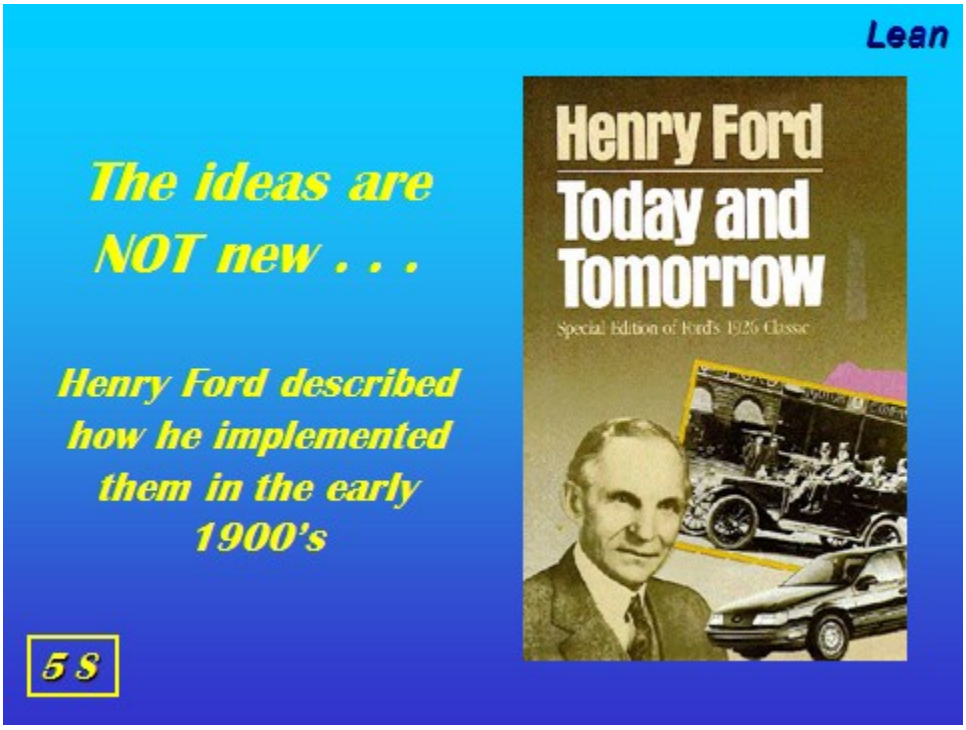
Slide 26

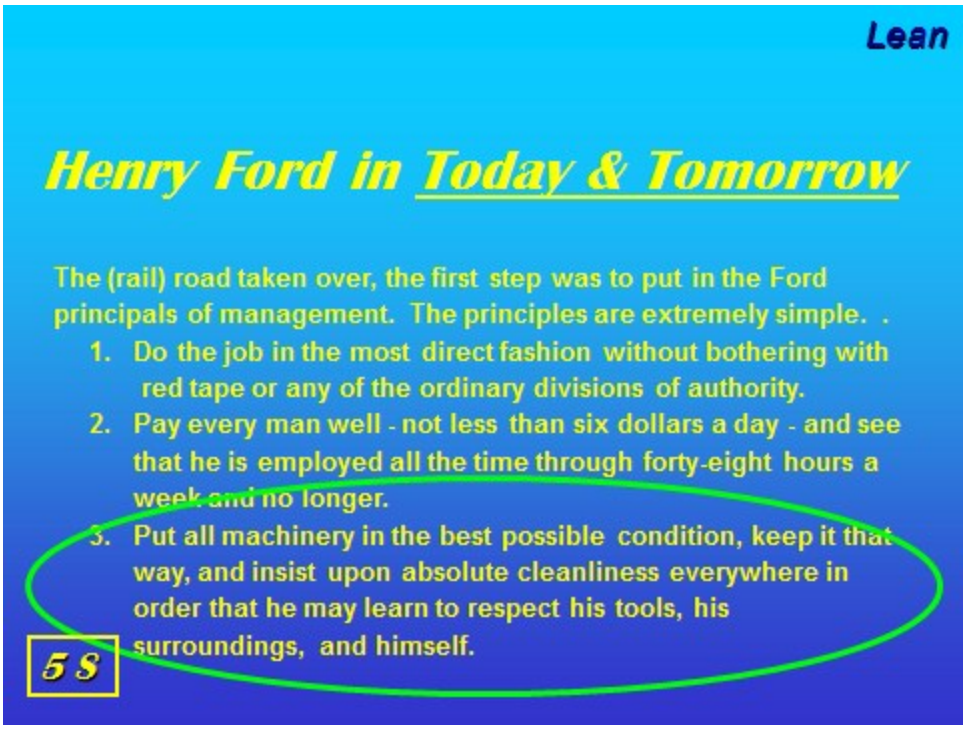


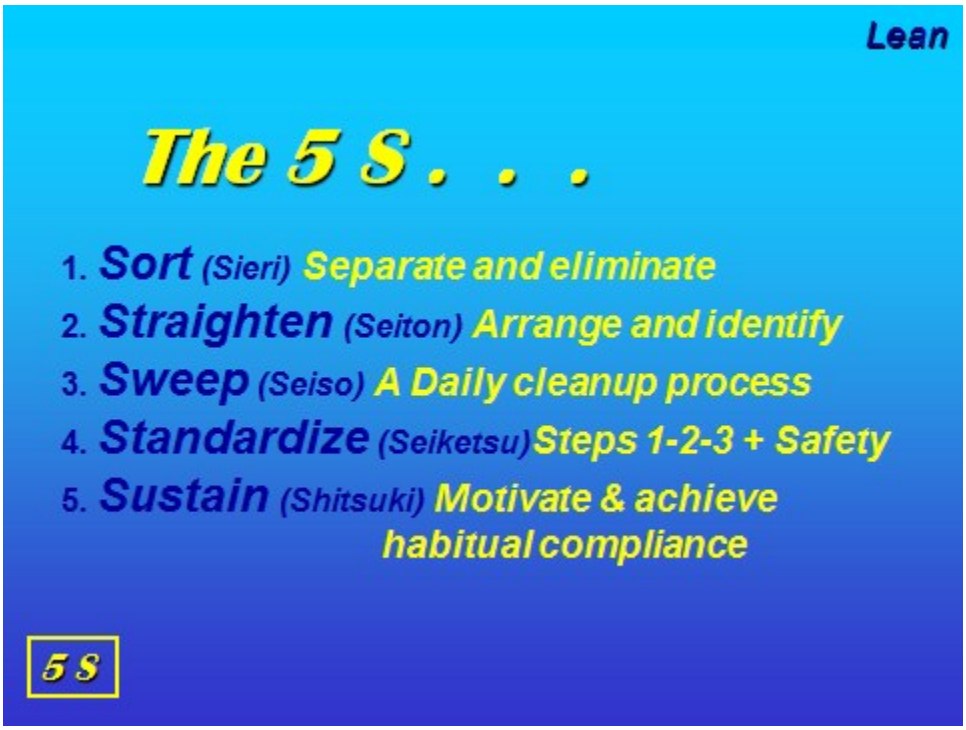
1. On a piece of paper write down the 5S's and why they are important.
2. You are a shop manager, Create a check list for your employees using this information to evaluate their workspace to make sure they are implementing 5S.
3. Take evaluations and if things need to be fixed have the students come up with ideas that would benefit them, and have them involved, not just the teacher assigning tasks.

Sample Presentation from Local Manufacturing Firm






Lean
Henry Ford in Today & Tomorrow
The (rail) road taken over, the first step was to put in the Ford principals of management. The principles are extremely simple. .
1. Do the job in the most direct fashion without bothering with red tape or any of the ordinary divisions of authority.
2. Pay every man well - not less than six dollars a day - and see that he is employed all the time through forty-eight hours a week and no longer.
3. Put all machinery in the best possible condition, keep it that way, and insist upon absolute cleanliness everywhere in order that he may learn to respect his tools, his surroundings, and himself.
5 S

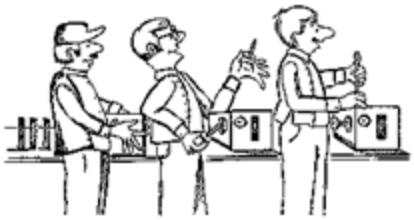

Lean
The 5 S . . .
1. Sort (Sieri) Separate and eliminate
2. Straighten (Seiton) Arrange and identify
3. Sweep (Seiso) A Daily cleanup process
4. Standardize (Seiketsu) Steps 1-2-3 + Safety
5. Sustain (Shitsuki) Motivate & achieve habitual compliance
5 S

Lean

1. Sort

Before

After



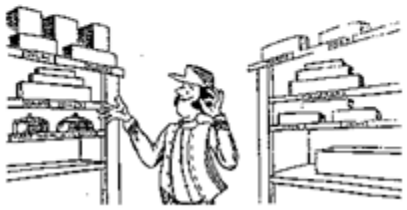
5 S

Lean

2. Straighten

Before

After



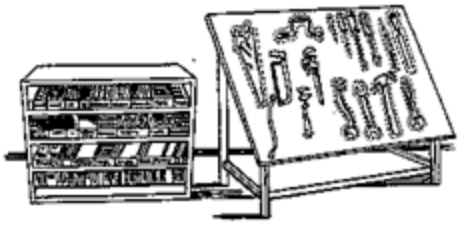
5 S

Lean

2. Straighten

Before

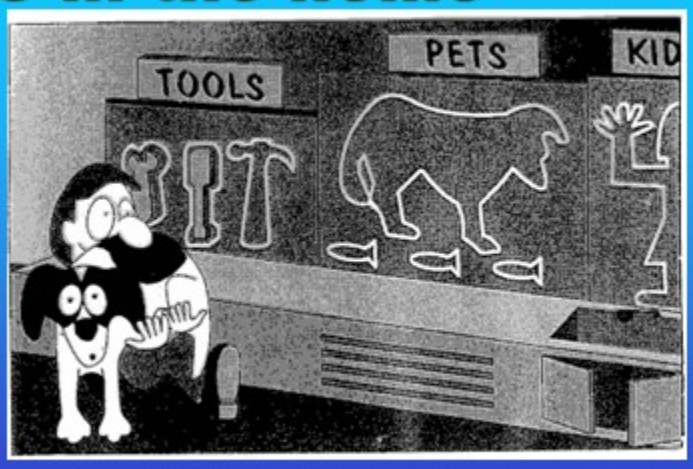
After



5 S

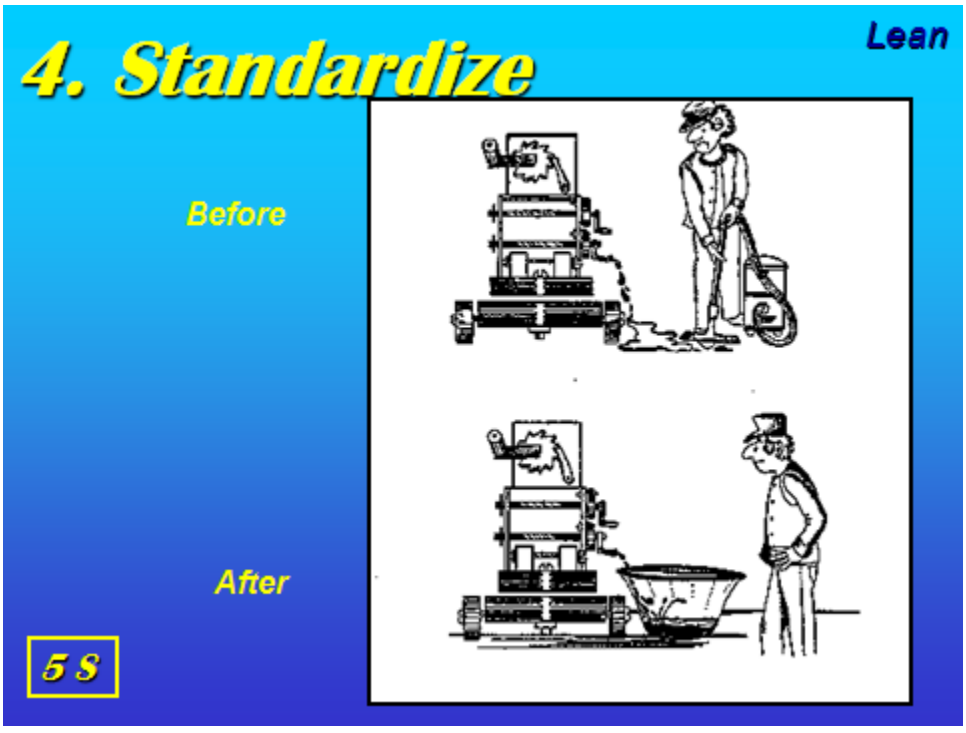
Lean

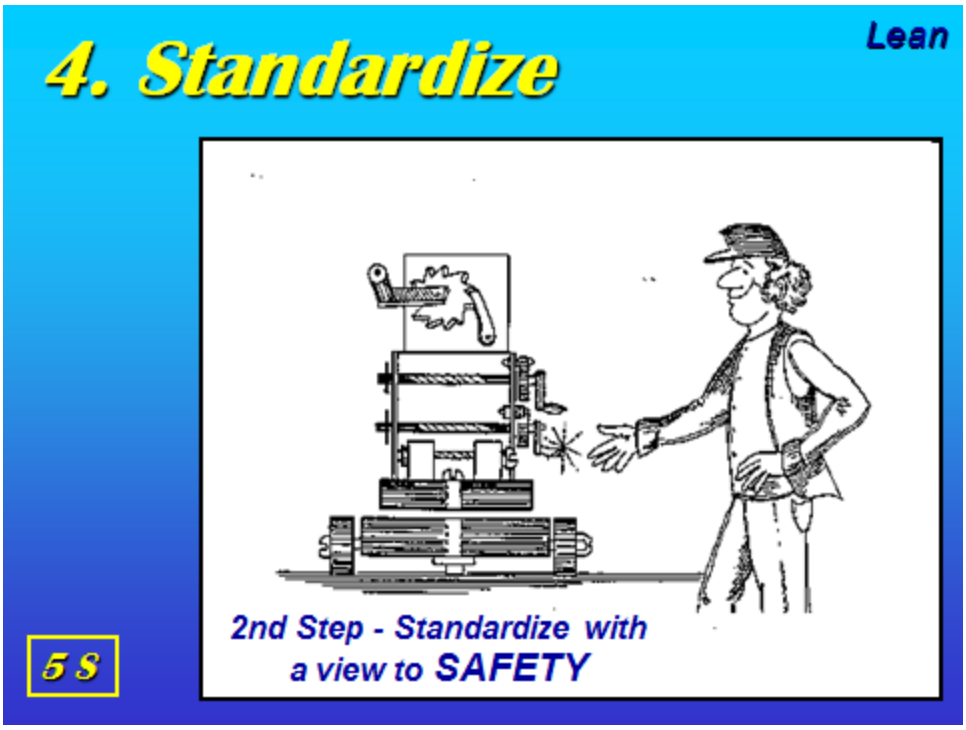
5 S in the home

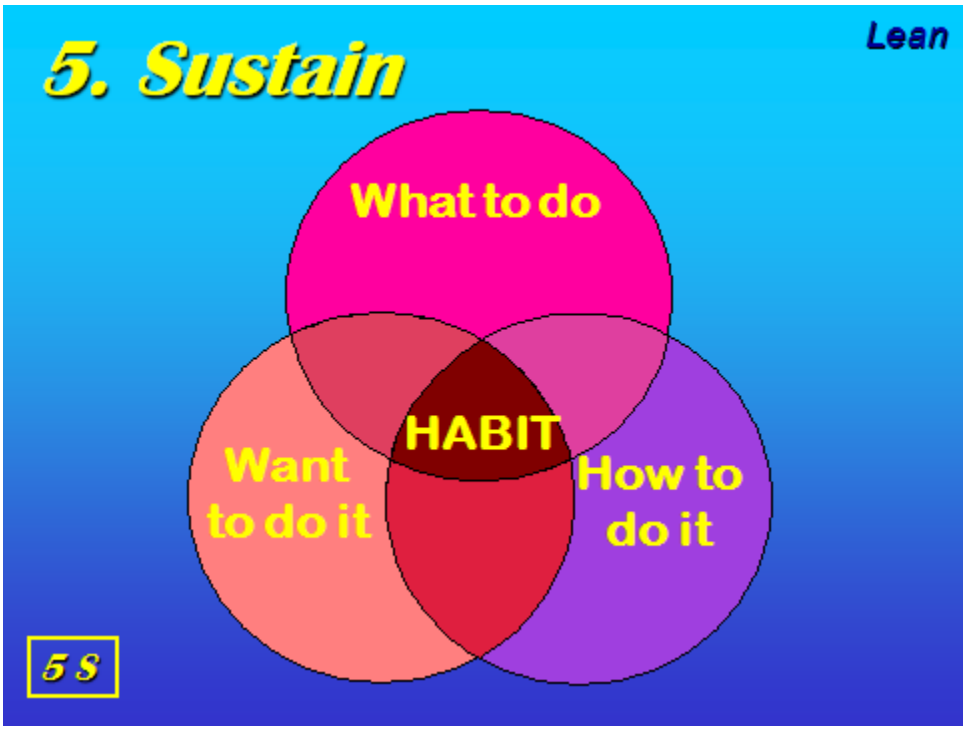


5 S


3. Sweep
and Clean
Before
After
5 S


Lean
4. Standardize
Before
After
5 S


Lean
4. Standardize
2nd Step - Standardize with
a view to SAFETY
5 S


Lean
5. Sustain
What to do
HABIT
Want
to do it
How to
do it
5 S

Works Cited

Survey Sources

http://www.keene.edu/crc/forms/designingsurveysthatcount.pdf

http://writing.colostate.edu/guides/research/survey

http://oqi.wisc.edu/resourcelibrary/uploads/resources/Survey_Guide.pdf

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Videos used

Introduction to Lean: http://www.youtube.com/watch?v=OACMvw6G4Lg&feature=plcp

1. Sort: http://www.youtube.com/watch?v=s2xqBMdKjG0&feature=relmfu

2. Set: http://www.youtube.com/watch?v=i5bPmXr2yGs&feature=relmfu

3. Shine: http://www.youtube.com/watch?v=B1j8jK9dE6Y&feature=relmfu

4. Standardize: http://www.youtube.com/watch?v=r3cYjjEt3UM

5. Sustain: http://www.youtube.com/watch?v=8ZbXG3Hbt4w&feature=relmfu

The company that created all of these videos is Manufacturing Skills Australia and their website is http://www.mskills.com.au/Default.aspx.